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UNIVERSITY OF ALBERTA

THE EFFECT OF ULTRASOUND ON PAIN THRESHOLD

BY

SRI MARDIMAN

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

DEPARTMENT OF PHYSICAL THERAPY

Edmonton, Alberta

SPRING 1994

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECT OF ULTRASOUND ON PAIN THRESHOLD submitted by SRI MARDIMAN in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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Dr. Brian Fisher.

Date : November 12, 1993

DEDICATION.

This work is dedicated with love to my wife - Sudarni, and my sons - Agung Dewanto, Ustika Anggono, Tejo Srinoto- who encouraged and supported me to study in Canada.

ABSTRACT.

Previous studies examining the effect of ultrasound on pain threshold were only concerned with cutaneous heat and prickling pain. Since different types of pain may respond differently to the same treatment, other types of pain such as dull pain need to be studied.

The purpose of this study was to examine the effect of ultrasound on threshold of dull pain. Twenty healthy pain-free volunteers (12 male, 8 female) ranging in age from 22 to 51 years participated in the study. A within subject design was used. The experimental and the control (sham ultrasound) arms were randomly allocated. The subjects and the tester were blinded to the experimental/control allocation. Ultrasound of 1.1 MHz at 1.0 watt/cm^2 was applied on the dorsal aspect of the experimental forearm for five minutes while the control arm received no ultrasound energy. Another neutral spot on the ventral aspect of each arm was tested, but received neither treatment nor sham ultrasound. Pain thresholds were measured before and two minutes following ultrasound/sham ultrasound on the treatment and neutral areas using a dolorimeter. The pain thresholds obtained were analyzed with a three-way ANOVA with repeated measures on all factors (arm x time x site) and Newman Keuls post hoc analysis.

It was found that treatment ultrasound significantly increased pain threshold while sham ultrasound did not. The

pain threshold following treatment ultrasound was significantly higher than that following sham ultrasound. The pain threshold of the dorsal aspect of the upper forearm was significantly lower than that of the ventral aspect of the upper forearm. There was no change in pain threshold on the neutral area on both upper forearms following ultrasound. There was no significant difference in pain threshold on the same aspect of the upper forearm bilaterally.

It is concluded that continuous 1.1 MHz ultrasound applied at 1.0 watt/cm^2 for five minutes can increase the threshold of dull pain in healthy subjects.

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1. INTRODUCTION.

Rationale.

Pain is a common problem treated by physiotherapists. One of the modalities used in this treatment is ultrasound (Partridge 1987). Although therapeutic ultrasound has been used extensively in physiotherapy since the 1950s (Holmes and Rudland 1991), the effect of ultrasound on different types of pain has not been thoroughly evaluated.

Pain, as defined by The International Association for the Study of Pain, is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (Feuerstein 1985). Three aspects of pain have been acknowledged, i.e emotional, cognitive and sensory aspect. The sensory aspect of pain is concerned with time, space and intensity (Weisenberg 1985). It is the component of pain usually considered to be most affected by physiotherapy modalities.

Pain is the most frequent complaint that motivates patients to seek medical care (Paris 1988). If the treatment is not effective, the pain can become chronic. Based on the report of the Division of Biostatistics and Epidemiology of the National Institute of Neurologic and Communicative Disease and Stroke, it was estimated that in 1989, 75 - 80 million Americans had chronic pain and the cost of its treatment was 65 - 75 billion dollars per year (Bonica 1992). In addition,

it is recommended by Yeah et al (1992) that all persons with chronic pain be referred to physical therapy. Although not all chronic pain patients will benefit from physical therapy, Yeah et al's statement emphasizes the problem of pain in physical therapy.

Ultrasound is a form of vibrating energy with frequencies higher than the audible range, i.e greater than 20,000 Hz (Mortimer 1982). It is recommended by a number of authors for the treatment of pain (Partridge 1987). Its widespread application indicates clinical acceptance (Maxwell 1992). Although it has been claimed valuable in the treatment of a wide range of clinical conditions including pain, there have been few reports of randomised, controlled clinical trials to evaluate its efficacy (Lundeberg et al 1988).

Holmes and Rudland (1991), in their review, reported conflicting results of the effectiveness of ultrasound for the relief of pain. Some investigators reported that ultrasound was effective in the relief of pain in certain conditions, but some others reported that it was ineffective. The different conclusions may be due to differences in the treatment parameters and the methodology such as:

a. the stage of the condition when the ultrasound started to be given.
b. the nature or the diagnosis of the condition treated.
c. the dose of the ultrasound given.
d. the frequency of the ultrasound used.

e. the site of the application of the ultrasound.

The acuteness of pain may be another factor affecting the efficacy of ultrasound. Ultrasound applied for the relief of pain in patients with Herpes Zoster was reported effective by Garrett and Garrett (1982), but ineffective by Payne (1984). The pain treated by Garrett and Garrett (1982) was mostly in an acute stage, while the pain treated by Payne (1984) was in a chronic stage (more than two years after the onset of the disease).

Different results may also be due to differences in diagnoses. Ultrasound was reported effective in the relief of shoulder pain by Munting (1978), but ineffective by Inaba and Piorkowski (1972). Munting (1978) treated patients with frozen shoulder or capsulitis, while Inaba and Piorkowski (1972) treated hemiplegic patients. The pain in hemiplegic patients may result from various causes such as spasticity, central nervous system disturbance, subluxation, brachial plexus injury (Garrison 1991). The pain in capsulitis is due to restricted movement resulting from inflammation of the joint capsule. Thus the type of pain treated in both studies was different and may have affected the efficacy of ultrasound.

There have been experimental studies on the effect of ultrasound on pain threshold. Lehman et al (1958) used radiant heat as a pain stimulus in measuring pain threshold. It was found that ultrasound increased pain threshold on the

experimental side and there was no increase of pain threshold on the control side. Hardy et al (1940) found in their study that pain and heat were separate sensations and they were not served by the same receptors. Therefore, the results of Lehman et al may not be applicable to other types of pain such as dull pain.

Electrical current was used as a pain stimulus by Williams et al (1987). It was found that ultrasound decreased pain threshold. However, the study was only concerned with cutaneous prickling pain. They also found that ultrasound of 3.3 MHz produced a greater decrease in cutaneous pain threshold when compared with ultrasound of 1.1 MHz. The different results may be due to the difference in the depth of penetration of different frequencies of ultrasound. The higher the frequency, the more superficial the effect will be (Summer and Patrick 1964).

Other types of pain such as dull pain need to be studied because it has been found that different types of pain can respond differently to the same stimulus. Mannheimer and Lampe (1984) reported from their clinical observation that superficial pain responded very well to conventional transcutaneous electrical nerve stimulation (Tens), while deep achy and longstanding discomfort responded better to strong, low-rate, burst stimulation of Tens. Simmonds et al (1992) found that Tens increased the threshold of dull pain but it had no effect on the threshold of sharp pinching pain. Thus,

ultrasound may be more or less effective with different types of pain.

To the author's knowledge, there have been no well controlled studies examining the effect of ultrasound on experimental or clinical pain of a dull nature. The purpose of this study was to examine the effect of ultrasound on pain threshold produced by a pressure dolorimeter (dull pain).

Hypothesis.

The hypotheses were :

a. There would be an increase in pain threshold following ultrasound.
b. There would be no change in pain threshold following sham ultrasound.
c. The pain threshold on the experimental arm following ultrasound would be higher than that on the control arm following sham ultrasound.
d. There would be no change in pain threshold in an untreated area on either the control or experimental arm.

Definition.

Pain threshold is that point at which pain is just perceived during an ascending series of stimuli (Wolff, 1983). The pain threshold is thus an index of minimal pain, a level at which there is no or only little suffering.

Ultrasound is a form of vibrating energy with frequencies

higher than the audible range, i.e higher than 20,000 Hz (Mortimer, 1982). Therapeutic ultrasound has frequencies between 0.5 MHz and 5 MHz (Haar, 1987).

Sham ultrasound is ultrasound which is applied in the usual manner but no energy is delivered into the tissues.

A dolorimeter is a force gauge fitted with a rubber disc to measure the quantity of the stimulus required to evoke pain (Fischer 1987).

2. LITERATURE REVIEW.

Overview.

This chapter reviews the problem of pain, the physiological basis of pain relief with ultrasound, the effects of ultrasound on experimental and clinical pain, and the reliability and validity of the dolorimeter. These areas are discussed in relation to the need for a study examining the effect of ultrasound on dull pain.

Problem of pain.

The number of patients with pain is large and the cost of its treatment is high (Bonica 1992). When the pain becomes chronic, the patients tend to become depressed so that the problem becomes complicated (Clark Mims 1989).

Pain experience consists of the actual noxious stimulus and the emotional and cognitive reaction to the stimulus (Paris et al 1988). Severe acute pain arouses considerable anxiety in almost everyone and behaviour associated with it is directed towards an urgent search for relief. When the pain is relieved, the anxiety level tends to decrease (Bond 1983).

Chronic pain may give rise to a serious social problem with potential consequences for the individual, his/her family, and the community (Clark Mims 1989). The patient with chronic pain frequently becomes depressed as a result of loss of health, loss of enjoyable activities, loss of income and loss of the ability to fulfil his parental and spousal roles

(Clark Mims 1989). Bond (1983) also reported that patients with chronic pain experienced forms of depression such as lethargy, fatigue, emotional tension and disordered sleep. Atkinson et al (1991) found that the prevalence of depression was higher in men with low back pain when they were not referred to a pain clinic (Atkinson, et al, 1991). Sternbach (1974) suggested that patients with chronic pain will become more and more preoccupied with their pain.

It is obvious that pain is a serious problem. The medical treatment is not always effective in relieving pain. The number of patients with chronic pain is large. Based on the report of the Division of Biostatistics and Epidemiology of the National Institute of Neurologic and Communicative Disease and Stroke, it was estimated that in 1989 approximately 75 - 80 million Americans lived with chronic pain and the cost of its treatment was estimated between US $65 - $75 billion per year (Bonica 1992).

Physiological basis of pain relief with ultrasound.

Ultrasound is recommended by a number of authors for the treatment of pain (Partridge 1987). However, the physiological basis of pain relief with ultrasound has not been fully understood.

There are several theories on the mechanism by which ultrasound can reduce pain. The mechanisms include thermal effect (Lehmann et al 1958), release of histamine (Dyson

1987), decreased nerve conduction velocity (Griffin 1966) and the effect of vibration on the pain gate (Palastanga 1988, Zoppi et al 1991).

Lehmann et al (1958) found that ultrasound increased pain threshold. Since temperature was also elevated, the investigators concluded that the thermal effect of ultrasound was involved in the relief of pain. (Detail of the study is presented under the effect of ultrasound on experimental pain threshold). Madsen and Gersten (1961) also found an increase in temperature in subcutaneous tissues following ultrasound. No relation between pain and temperature was measured. It can be concluded from the above two studies that the thermal effect is a potential mechanism by which ultrasound can reduce pain.

It has been demonstrated that low dose pulsed ultrasound can stimulate the release of histamine from mast cells both in vivo and in vitro (Dyson 1987, Fyfe and Chahl 1984). Histamine caused vasodilation of local blood vessels resulting in the acceleration of the removal of chemical substances such as bradykinin which caused pain (Michlovitz 1986). In this case, it would appear that mechanical effect of ultrasound on the mast cell can lead indirectly to the relief of pain.

Ultrasound was reported to be beneficial to the recovery of inflammation resulting in the relief of pain. However, the results of some studies were conflicting. Middlemast and Chatterjee (1978) reported that ultrasound had a better effect

on inflammation in soft tissue injuries compared with thermotherapy (infra red, short wave diathermy, wax bath). Binder et al (1985) also reported that the rate of recovery in patients with lateral epicondylitis was significantly better in a treatment group compared with that in a placebo group. However, Goddard et al (1983) reported that ultrasound had no effect on the inflammatory oedema and inflammatory infiltration into irritant sponges implanted subcutaneously in rats. Hashish et al (1986) also reported that ultrasound had no effect on inflammation in 150 patients following surgical removal of impacted lower third molars. The different results may be due to the difference in treatment time. In this study, there was no inflammation, thus this mechanism of pain relief would not be evident.

It is known that vibration can increase pain threshold (Zoppi et al 1991, Palmesano et al 1989) probably by exciting A-beta fibres which close the gate mechanism in the spinal cord. Pain threshold produced by electrical current was increased after application of vibration at 30 and 300 Hz (Zoppi et al 1991) and 120 Hz (Palmesano et al 1989). These results may not be applicable to vibration of high frequencies produced by ultrasound. Lundeberg et al (1984) found that the best pain reducing effect of vibrations was obtained with frequencies between 50 and 200 Hz. Higher frequencies produced less pain relief. Ribot-Ciscar et al (1989) reported that mechanoreceptors sensitive to mechanical vibrations could

respond up to 280 Hz. Thus, vibrations produced by ultrasound may not be involved in the mechanism of pain relief.

Lehmann and Latour (1989) assumed that any modality causing a decrease in nerve conduction would result in pain relief. Griffin (1966) felt that in fact a decrease in nerve conduction was an important mechanism for the relief of pain with ultrasound. However, reports on the effect of ultrasound on the nerve conduction velocity are conflicting (Currier et al 1978, Halle et al 1981, Madsen & Gersten 1961, Cosentino et al 1983, Kramer 1985, Rennie 1985).

Two studies (Madsen and Gersten 1961, Cosentino et al 1983) found a small decrease (about 2%) in nerve conduction velocity following ultrasound. Madsen and Gersten (1961) studied the effect of ultrasound on the conduction of the ulnar motor nerve in 28 normal subjects. Ultrasound of 1 MHz was applied at different intensities (0.88 watts/cm^2, 1.28 watts/cm^2 and 1.92 watts/cm^2) for 5 minutes to the whole ulnar aspect of the forearm. It was found that the conduction velocity decreased by 2% with 0.88 watts/cm^2 and 1.28 watts/cm^2, and by only 0.8% with 1.92 watts/cm^2. The investigators also found that there was 0.5^oC increase in temperature in subcutaneous tissues. With 1.92 watts/cm^2, the effects on temperature and nerve conduction velocity became doubled when the insonated area decreased by one-half. No statistical analysis was done.

Cosentino et al (1983) studied the sensory branch of the

median nerve in 13 normal subjects (10 subjects in the experimental group and three subjects in the sham group). The experimental group received ultrasound of 1 MHz at three different intensities (0.5 watts/cm^2, 1.0 watts/cm^2 and 1.5 watts/cm^2) for 10 minutes each with intervals of 48 hours. The sham group received no ultrasound. There was no significant change in sensory nerve conduction velocity after ultrasound in either group following ultrasound.

Two other studies (Currier et al 1978, Halle et al 1981) found increased nerve conduction velocity following ultrasound. Currier et al (1978) studied the effect of ultrasound on the sensory nerve conduction velocity of the lateral cutaneous branch of the radial nerve. Five healthy volunteers were recruited without a control group. Both arms were studied to increase the sample size (n= 10). Application of ultrasound of 1 MHz at 1.5 watts/cm^2 for five minutes resulted in a 4% decrease in conduction latency. The result showed that the nerve conduction velocity increased with ultrasound. Halle et al (1981) compared the effect of ultrasound and infra red on nerve conduction latency of the radial nerve in 10 healthy volunteers. The subjects were randomly allocated into a group receiving ultrasound first and a group receiving infra red first. Ultrasound of 1 MHz at 1.0 watt/cm^2 was applied until the subcutaneous temperature increased by 1.2^oC. The mean time of applications was 13.2 minutes. There was a significant decrease in the nerve

conduction latency with both treatments.

Kramer (1985) compared the effects of six different intensities of ultrasound (0.0, 0.5, 1.0, 1.5, 2.0, 2.5 watts/cm^2) on the sensory ulnar nerve conduction velocity by measuring the antidromic sensory nerve latencies in 11 normal subjects. An ANOVA confirmed a significant increase in nerve conduction velocity following ultrasound with 1.5, 2.0 and 2.5 watts/cm^2, no significant increase with 0.5 and 1.0 watt/cm^2, but a significant decrease with 0.0 watt/cm^2. There was a significant increase in tissue temperature following ultrasound with 2.0 and 2.5 watts/cm^2, no significant increase with 1.0 and 1.5 watts/cm^2, but a significant decrease with 0.0 and 0.5 watts/cm^2. However, Pearson product moment correlation showed no correlation between the change in tissue temperature and the associated change in nerve conduction velocity.

Rennie (1985) compared the effects of three different frequencies of ultrasound (0.75, 1.5, 3.0 MHz) on the motor and sensory nerve conduction velocities of the ulnar nerve in 19 female normal subjects. Those three different frequencies were applied at 1.5 watts/cm^2 for 5 minutes each. Each subject acted as her own control by receiving ultrasound at 0.0 watt/cm^2. There was a minimum of 24 hours between protocols. The motor and sensory nerve conduction velocities were measured with an EMG. Tukey tests demonstrated a significant increase in motor and sensory nerve conduction velocities

following ultrasound of all three frequencies. There was a significant decrease in motor and sensory nerve conduction velocities following placebo ultrasound due to the cooling effect of the ultrasound gel.

The results of the above studies suggest that there is no consistent pattern of the influence of ultrasound on nerve conduction velocity. In those studies they were measuring the nerve conduction velocities of the fastest nerve fibres, ie large diameter nerve fibres. These fibres do not carry information on nociception. There has been no information on the effect of ultrasound on the small diameter nerve fibres. Thus, there has been no evidence that a decrease in nerve conduction velocity is involved in the mechanism of pain relief with ultrasound.

<u>The effect of ultrasound on experimental pain threshold.</u>

Wolff (1983) has described some advantages to using experimental pain to study human pain. They include:

a. The intensity of the stimulus used to evoke pain can be controlled and measured quantitatively.
b. Pain measurement involves more of the sensory component of pain so that the measurement is less influenced by extraneous variables.
c. The stimulus is reproducible.
d. Experimental pain permits comparison of minimal with maximal pain within the same experimental session.

However, there are some disadvantages to using experimental pain such as:

a. The experimental pain serves as a model for acute pain, not for chronic pain.

b. The resultant experimental pain may not bear a perfect relationship to clinical pain.

Lehmann et al (1958) found an increase in pain threshold following application of ultrasound. Lehman et al (1958) insonated the ulnar nerve at the elbow in one experiment and the pad of the little finger in another experiment. Ultrasound was applied at 1.5 watts/cm^2 for 2 minutes and the pain threshold to radiant heat was measured on the palmar pad of the little finger. The corresponding area on the the other side of the body received no ultrasound and was used as a control. The pain threshold increased with both applications of ultrasound, but there was no increase in pain threshold on the control side.

Williams et al (1987) compared the effect of 1.1 MHz continuous wave, 1.1 MHz pulsed wave, 3.3 MHz continuous wave and 3.3 MHz pulsed wave on pain threshold to electrical current. All four protocols decreased the pain threshold, but there was no control situation. The 3.3 MHz ultrasound produced the greatest increase in pain threshold. The 1.1 MHz pulsed wave produced the same effect as 1.1 MHz continuous wave. The 3.3 MHz pulsed wave also produced the same effect as 3.3 MHz continuous wave. The total time that ultrasound was

delivered was the same in both pulsed and continuous waves.

These two studies were concerned with thermal and electrical pain and the result may not be applicable to other types of pain. Hardy et al (1940) found that heat and pain were separate sensations and they were not served by the same receptors. Electrical pain is cutaneous prickling pain (Forster and Palastanga 1981). However, the most common type of pain reported in Montreal hospitals was deep pain (Abbot et al 1992).

Simmonds et al (1992) and Mannheimer and Lampe (1984) also found that different type of pain responded differently to the same treatment. Simmonds et al (1992) found that transcutaneous electrical nerve stimulation (Tens) increased the threshold of dull pain but it had no effect on the threshold of sharp pinching pain. Mannheimer and Lampe (1984) reported from their clinical Tens observations that superficial pain responded well to conventional Tens, but deep achy and longstanding discomfort responded better to strong, low rate, burst stimulation of Tens.

The studies on experimental pain were only concerned with cutaneous heat and prickling pain. Other types of pain such as dull pain need to be studied.

The effectiveness of ultrasound in the relief of clinical pain.

Pain is one of the symptoms for which ultrasound is

recommended by a number of authors (Partridge 1987). Some investigators found that ultrasound was effective in the relief of clinical pain (Munting 1978, Garrett and Garrett 1982, Aldes et al 1958, Nwuga 1983,Girardi et al 1984) while others (Inaba and Piorkowski 1972, Payne 1984, Everett et al 1992, Haker and Lundeberg 1991) found that it was not. The different results may be due to the differences in the types of pain studied or the doses of ultrasound given.

Ultrasound was reported ineffective for the treatment of shoulder pain by Inaba and Piorkowski (1972), but it was reported effective by Munting (1978). The nature of the conditions treated in both studies was different. Inaba and Piorkowski (1972) studied 33 hemiplegic patients who were randomly divided into three groups: control (n=13), treatment (n=10) and placebo (n=10) groups. Exercises and arm positioning were given to all groups. Ultrasound at 0.5 - 2.0 watts/cm^2 was only given to the treatment group for 5 minutes. The effectiveness of ultrasound in the relief of pain was determined by measuring changes in pain-free range of movement of flexion, abduction and rotation of the shoulder. The result of the ANOVA indicated no significant differences among the three groups. The investigators stated that the ultrasound had no effect on their subjects. However, the conclusions may not be valid because there was no direct measurement of the pain, the sample size was small and the type of pain may have varied from patient to patient.

Munting (1978) studied 20 patients with frozen shoulder or capsulitis and divided them into a treatment group (n=11) and a control group (n=9). Ultrasound of 1.5 MHz, continuous wave, at 0.5 watts/cm^2 for 3 minutes, increasing to four to five minutes on consecutive days was applied on the anterior, posterior and inferior aspects of the joint at each session. The investigators reported that 81% of the treatment group and 44% of the control group had pain relief. No statistical analysis was done. The result would likely not be statistically significant because the sample size was small.

Ultrasound was reported effective for the treatment of Herpes Zoster by Garrett and Garrett (1982), but it was reported ineffective by Payne (1984). Most of the patients treated by Garrett and Garrett (1982) were in an early stage of the disease. Continuous ultrasound of 1 MHz at 0.25 watts/cm^2 was applied at the rate of 2 minutes for every 12 cm^2 area. In extra sensitive areas, pulsed ultrasound was used. No control group was recruited. Most of the subjects had considerable pain relief after the first treatment and all were pain-free in 1 - 2 weeks. However, the improvement may be partly due to spontaneous recovery (natural history) of the disease.

Payne (1984) applied ultrasound of 1 MHz at 0.25 watts/cm^2, continuous wave for one minute per 2 cm^2 surface area. Seventeen patients with post-herpetic neuralgia (two to 17 years after the onset) were recruited. There was no control

group. The investigator reported that 13 patients had no change in their symptoms, two patients were better and the remaining two patients were worse. No statistical analysis was done. The ineffectiveness of the ultrasound in this study may be due to the chronicity of the cases. Some of the subjects were reported to be suffering from depression. The two studies treated patients with the same diagnosis, but in different stages of the disease. The types of pain treated may be different between the two studies. No spontaneous recovery was expected in patients treated by Payne (1984).

Three studies (Aldes et al 1958, Nwuga 1983 and Girardi et al 1984) found that ultrasound was effective for the treatment of back pain. However, the results may not be due to merely ultrasound because the patients were also given other forms of treatment such as hot pack, massage (Aldes et al 1958) and galvanic stimulation (Girardi et al 1984).

Aldes et al (1958) applied ultrasound of 1 MHz at 0.3-0.8 watts/cm^2 on patients with prolapsed intervertebral disc until 12 treatments had been completed. From 209 cases, 180 patients (86%) had total relief of symptoms and returned to full activity while 29 patients (14%) had little or no relief. The investigators also compared the group receiving ultrasound with a group receiving short wave diathermy. Ultrasound was reported to be more effective. From 148 cases treated with short wave diathermy, 52% of them had pain relief. There was no method of pain measurement reported and no statistical

analysis.

Nwuga (1983) reported the same findings as Aldes et al (1958). Eighty one male patients with confirmed diagnosis of prolapsed lumbar intervertebral disc were grouped into treatment (n=27), placebo (n=25) and control (n=29) groups. Ultrasound was applied on the affected area at 1-2 watts/cm^2 (determined by the patient's tolerance) for 10 minutes. The placebo group received sham ultrasound. The control group received only analgesics. All groups were on bed rest. Pain was measured with a 4-category assessment scale (1= pain free; 2= some residual pain; 3= fair improvement; 4= unchanged). Range of movement of flexion-extension, side flexion and rotation of the spine was also measured. An ANOVA showed significant increase in the lumbar range of motion in flexion-extension and height of straight-leg-raise, and a significant decrease in pain in the treatment group after 4 weeks.

Girardi et al (1984) studied 10 patients with chronic lumbar pain of any origin. No control group was recruited. Ultrasound of 1 MHz, pulsed wave (duty cycle 25%), at 1 watt/cm^2 was applied. The treatment time varied from patient to patient. The result showed a significant decrease in pain intensity following ultrasound.

Inadequate treatment time may be another factor resulting in the ineffectiveness of the treatment. Everett et al (1992) studied 69 patients with persistent post-natal perineal pain and dyspareunia. The subjects were randomly allocated into

treatment and placebo groups. Ultrasound of 3 MHz at 0.5 watts/cm^2, pulsed wave with 1:1 pulse interval was given for 5 minutes so that the effective treatment time was only two minutes and 30 seconds. Treatment was given three times a week until eight treatments had been completed. The pain was assessed with a self-administered questionnaire. The investigators reported that women in the treatment group tended to report less perineal pain, but there was no significant difference between the two groups.

Haker and Lundeberg (1991) reported that pulsed wave ultrasound had no effect on lateral epicondylalgia (tennis elbow). They studied 43 patients and randomly allocated the subjects into a treatment group (21) and a control group (22). Ultrasound of 1 MHz, pulsed wave with duty cycle of 20% at 1 watt/cm^2 was applied for 10 minutes. The effective treatment time was only 2 minutes. The ultrasound was given three times weekly until 10 treatments had been completed. The pain was measured with a dynamometer with a rubber balloon compressed in the hand. The patients were instructed to squeeze the balloon and to stop the pressure when pain was experienced over the lateral epicondyle. The result of Mann-Whitney U-test indicated no significant difference in pain threshold between the two groups. In both studies the effective treatment time was probably too short to produce therapeutic effects (Dyson 1987).

Many studies examining the effect of ultrasound on

clinical pain lack control groups, and have small sample sizes. The different results may be due to different types of pain treated and different outcome measures. The ineffectiveness of the treatment may also be due to inadequate treatment time. A well-controlled study needs to be done to provide more information on the effect of ultrasound on pain.

Reliability and validity of a dolorimeter.

A dolorimeter is a force gauge used for the evaluation of pain sensitivity and pressure perception (Fischer 1987, Brennum et al 1989). Force is applied through the dolorimeter at a constant rate of increase (Fischer 1987). In research, it is used to measure pain threshold and pain tolerance. Pain threshold is the amount of pressure that elicits the first sensation of pain. Pain tolerance is the point at which the subject withdraws and refuses to accept pain (Wolff 1983). Several authors have found that a pressure dolorimeter is a reliable tool to measure pain threshold (Reeves et al 1986, Ohrbrach and Gale 1989, Brennum et al 1989, McCarty et al 1965, Dahl et al 1990). It also has a high agreement with other tests of pain (Keele and Lond 1954, Harris and Rollman 1983), and is reported to be well suited for clinical and experimental purposes (Brennum et al 1989).

Five studies (Reeves et al 1986, Ohrbrach and Gale 1989, Brennum et al 1989, McCarty et al 1965, Dahl et al 1990) found that the dolorimeter had a high reliability for the

measurement of pain threshold. Details of these studies are presented in Table 2.1. Brennum et al (1989) used a pressure algometer equipped with a patient operated button. McCarty et al (1965) scored tenderness by subtracting the number of pounds of force needed to produce pain from 10. The scale ranged from 0 to 300 (30 joints x 10 points per joint). Each patient served as his/her own control.

The reliability of the dolorimeter could be affected by factors, such as:

a. The dolorimeter slipping off of the point of measurement (Reeves et al 1986). If this happens, the result may be less accurate.

b. Accurately locating the point of contact. Reeves et al (1986) found that marking the point of measurement increased the reliability.

c. Changes in the rate of application of force. McCarty et al (1965) and Keele and Lond (1954) reported that the rate of the application of force was an important factor. Slower rates produced higher scores. They believed that this was due to temporal summation of the impulses.

d. Disturbing environment and patient's cooperation (Hogeweg et al 1992, Keele and Lond 1954). It was reported from their observations that the method using a dolorimeter was partly subjective and dependent on the patient's cooperation. When the attention of the tester or the patient was diverted, the accuracy of the reading would suffer. Keele

and Lond (1954) suggested that the test should be done in a quiet room without a third person being present.

The validity of the dolorimeter has been studied by examining the correlation of its results with other methods of measuring experimental pain (Keele and Lond 1954, Harris and Rollman 1983). Keele and Lond (1954) compared the dolorimeter with Lewis' ischemic test and Hollander's test in 100 normal subjects. Lewis' test is a method of measuring pain threshold by isotonic squeezing of a sphygmomanometer bulb at a metronome rate of one per second. The pain threshold was the number of contractions previous to the appearance of slight ischemic pain. Hollander's test is a method of testing pain sensitivity by inserting a grate inside a sphygmomanometer cuff and noting the pressure at which the patient so stimulated begins to wince or change expression. The results were presented graphically and demonstrated good correlations between tests. The investigators also stated that the result obtained from one method could be converted into any of two others. However, they did not provide regression equations for the conversion.

Table 2.1. Studies examining the reliability of the dolorimeter.

Studies	Subjects	No.of meas.	Time interval	Rate of application	Sites	Results
Reeves et al (1986)	MPS n=15	4x/ss 1 ss	NA	1 kg/s	Trigger pts head, neck	intra: .72-.92 inter: .71-.92
Ohrbach & Gale 1989	Normal n=10	5x/ss 1 ss	5 min ws	.4 kg/s	masseter & ant temp m	intra: .83-.91
Brennum et al (1989)	Normal n=30	5x/ss 2 ss	5 min ws 1 wk bs	1.1 N/s	12 sites hands,feet	CV: 14%
McCarty et al 1965	RA n=12	2x/ss 4 ss	NA	2.27 kg/s	30 joints	intra S:5.6 pt inter S:4.8 pt
Dahl et al (1990)	Normal n=20	5x/ss 2 ss	48 hrs bs	10 kPa/s	T-10 & T-12 dermatome bilaterally	NS diff bs or betw T 1-3. T 4-5> T 1-3. T1=T2=T3.

Legend: intra : intrarater reliability. meas : measurement.
inter : interrater reliability. ws : within session.
NA : Not available. bs : between sessions.
RA : Rheumatoid arthritis. ss : session.
MPS : Myofascial Pain Synd. pt : point.
S : Standard Error of Meas. T : Test.

Harris and Rollman (1983) compared dolorimeter measures to those produced by cold and electric shock in 40 students (20 male and 20 female). Pain threshold for cold and pressure stressors was defined as the amount of time elapsed between the beginning of stimulation and the point at which it became painful. The pain threshold for electric shock was the current level at which the subject reported that its quality first changed from touch to pain. The investigators used a multitrait-multimethod matrix procedure developed by Campbell and Fiske (1959) to examine the validity of the three measures. The results of their study met the requirements for the validity:

a. Convergent validity. The correlations of the same measures (among thresholds or among tolerances) across stressors were significant. Five of the six comparisons met the requirement.

b. Discriminant validity:

Threshold measures of different instruments were more highly correlated than threshold and tolerance measures of the same or different instruments.

Some studies have found that the dolorimeter is a reliable and valid tool to measure pain threshold. The tool is reported to be well suited for clinical and experimental purposes. The examiner needs to be accustomed to the instrument for more accurate measurement.

Conclusion of the literature review.

Physiological effects of ultrasound support the statement that ultrasound can relieve pain. But, clinical investigators reported conflicting results. However, there were several problems with the design of the clinical studies. These problems can be summarized as the following:

a. The studies lacked control groups.
b. The sample sizes were small.
c. The outcome measures were often not well defined and were difficult to compare to each other.
d. The studies lacked statistical analysis.
e. A great variety of ultrasound treatment regimes were used in various studies.
f. The ultrasound dose may not have been adequate for reduction of pain.

Summary statement.

Pain is the most frequent complaint that motivates patients to seek treatment. It is one of the symptoms for which ultrasound is recommended. However, the effectiveness of ultrasound is still controversial.

Previous investigations examining the effect of ultrasound on pain threshold were only concerned with cutaneous heat and prickling pain. Since different types of pain respond differently to the same stimulus, other types of

pain such as dull pain need to be studied.

The purpose of this study was to examine the effect of ultrasound on dull pain threshold. The results of the study provide information on whether ultrasound can relieve dull pain.

Further study might be needed to establish the most effective ultrasound parameters such as frequency, treatment time and intensity, in the relief of dull pain.

3. METHOD.

Study Design.

The study was a within subject design. One arm received the experimental treatment and the other arm acted as a control. Both arms were tested for pain threshold before and two minutes after the treatment ultrasound or sham ultrasound (See Figure 3.1).

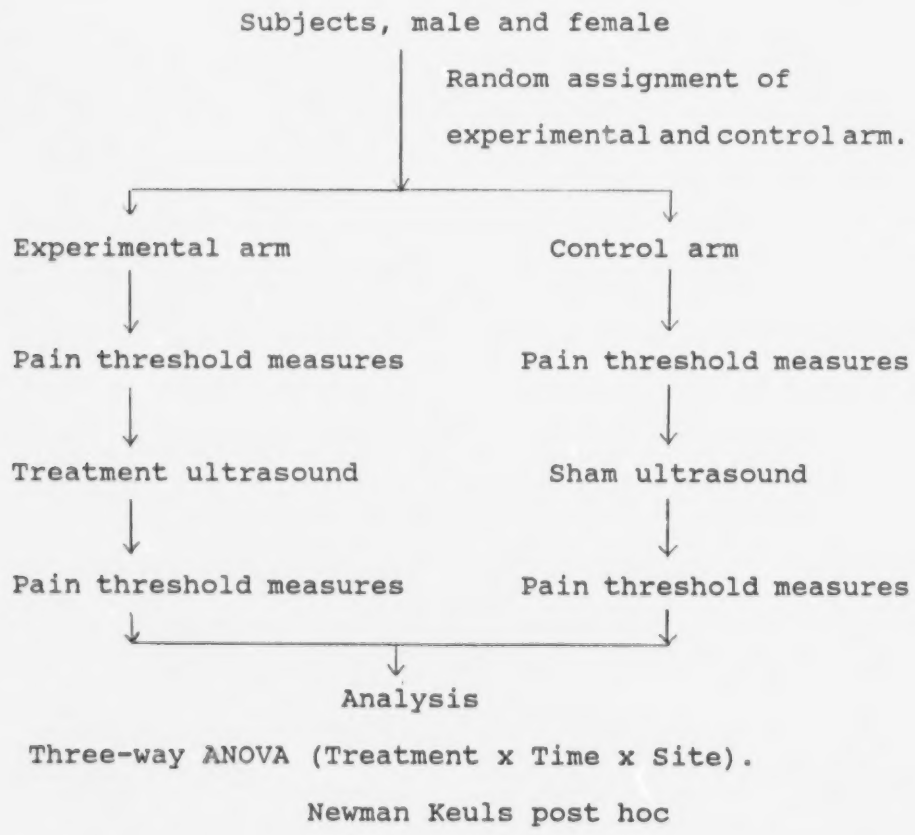

Figure 3.1. Flow chart of study protocol.

The corresponding area on the other side of the body was used as a control (See page 29) because:

a. there is a great deal of individual variability in pain threshold (Hardy et al 1940, Lehman et al 1958).
b. the pain threshold is different on different areas of the body (Hardy et al 1940, Lehman et al 1958, Ohrbach & Gale 1989, Brennum et al 1989, Fischer 1987).
c. the pain threshold is similar on the same part of the body bilaterally (Fischer 1987, Hogeweg et al 1992).
d. the effect of the ultrasound is limited to the area supplied by the insonated nerve distal to the site of application (Lehman et al 1958, Stewart et al 1982, Anderson et al 1951).
e. fewer subjects are required for a within subject design.

The experimental and control arm were randomly allocated by drawing out of a hat. The order of the insonation was also randomly allocated.

The study design used a double blinded method. The subjects and the tester were not informed of the allocation of the experimental and the control arm.

The study was conducted in Room 179 Corbett Hall, Faculty of Rehabilitation Medicine, University of Alberta.

Subjects.

Based on the standard deviation of pain threshold of 0.57 kg/cm^2 obtained from a pilot study and assuming an effect size

of 0.35, an alpha level of 0.05 and a power of 0.80, 17 subjects would be required to demonstrate a significant difference between arms or between times, or a significant interaction effect. In this study, 20 volunteers (12 male, 8 female) ranging in age from 22 to 51 years were recruited. All subjects signed a consent form (Appendix B) before participating in the study.

The exclusion criteria for the subjects were :

a. present pain.
b. any known or suspected upper extremity or cervical pathology.
c. previous surgery of upper limbs.
d. taking any medication.
e. pregnancy.
f. any previous experience with ultrasound.

Introductory information letters (Appendix A) were distributed to students and staff members at the University of Alberta. Subjects were recruited from staff members at the Faculty of Rehabilitation Medicine and students from the University of Alberta.

Testing.

The pain threshold was measured with a dolorimeter made by Pain Diagnostic & Thermography, Italy. It is a force gauge fitted by a rubber disc with a surface of 1 cm^2 (Figure 3.2). The force that can be measured is 0-11 kilograms. The device

is available in the physiotherapy laboratory, University of Alberta. It has been found to be reliable and valid (Fischer 1987, Keele and Lond 1954, Harris and Rollman 1983). Reeves et al (1986) found that the dolorimeter had coefficients of 0.72 to 0.97 for intrarater reliability and 0.71 to 0.89 for interrater reliability. The subjects were told that:

a. The pressure applied would be increased gradually up to the point at which they started feeling mild discomfort.
b. The pain threshold would be measured before insonation and 2 minutes after insonation on both arms.

Figure 3.2. Measurement of pain threshold with a dolorimeter.

The pain threshold measurement was taken on the treated area -the dorsal aspect of the upper forearms over the muscle bellies of the wrist extensors. Pain threshold of a neutral area - muscle belly of wrist flexors - was also measured. The point at which the pain threshold was measured was marked so that the second measurement was taken exactly at the same spot. The measurement spot on the treated area was 7 cm distal to the lateral epicondyle of humerus, on a line drawn from the lateral condyle of the humerus to the dorsal radial tubercle (Figure 3.3). The measurement spot on the neutral area was 10 cm distal to the medial epicondyle of humerus, on a line drawn from the medial epicondyle of humerus to the radial styloid process (Figure 3.4). The subjects were not able to see the amount of pressure applied during the test. The pressure was applied perpendicularly to the tissues and increased gradually at the rate of about one kilogram per second until the subjects started feeling mild discomfort (Figure 3.2). To make sure that the subjects understood how the pain threshold would be measured, each subject was given some experience with the dolorimeter on another part of the body before testing. The data was recorded in the data form (Appendix C).

The measurement of pain thresholds on the neutral areas were done to examine whether or not ultrasound produced a systemic effect. Besides, it could differentiate the effects on treatment, control and neutral areas. An area over the muscle belly of the wrist flexors was selected because its

pain threshold would be closer to that on the treated area compared to the pain threshold on distant areas such as the lower extremities.

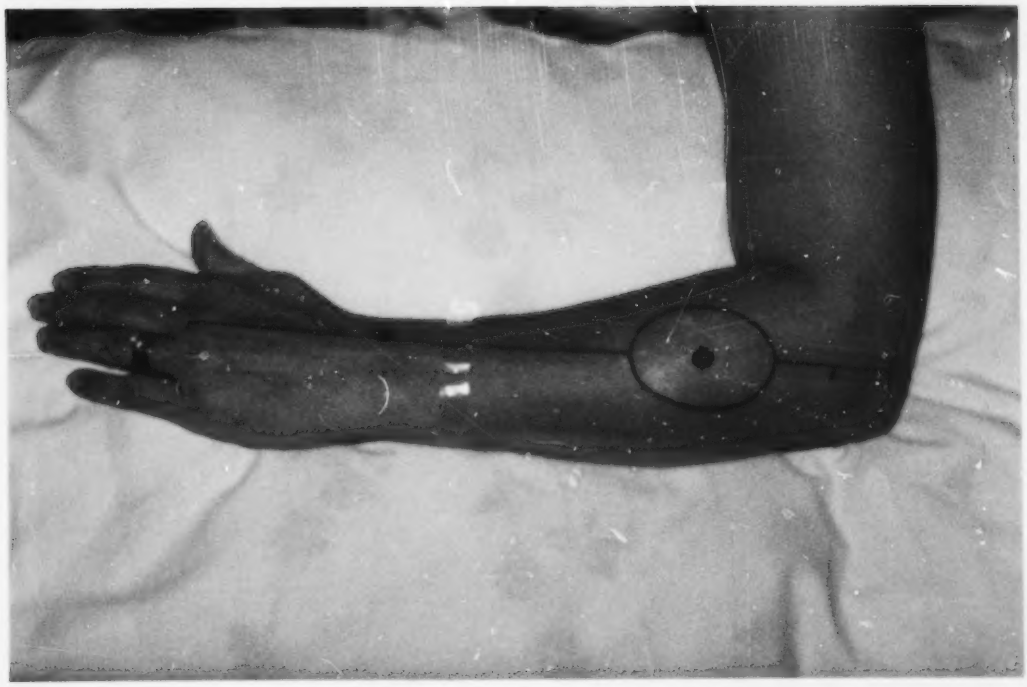

Figure 3.3. Assignment of the point of pain threshold measurement and area insonated.

Figure 3.4. Assignment of the point of pain threshold measurement on neutral area.

Treatment.

In this study, Therasonic Mark 3a, Ultrasonic Therapy Unit, Electro Medical Supplies (Greenham) Ltd, Wantage, Oxfordshire, England (Figure 3.5) was used. The specifications of the unit are:

Frequency : 1.1 MHz.

Transducer : 5 cm^2.

Maximum output : 3 $Watt/cm^2$.

The timer and the intensity of output of the unit were calibrated prior to the commencement of the study, at the middle and at the end of the study. The intensity of output was calibrated by using Ultraschalleistungsmessgerat, NMY-3 water balance, made in USSR (Figure 3.5). The timer was calibrated by using Gra-lab Universal Timer, Model 171, made by Dimco-Gray Co, USA. The equipments were available in the Electrotherapy Laboratory, Corbett Hall.

Ultrasound was applied over the muscle bellies of the wrist extensors because this area was even, had layers of soft tissues and was easily accessible. The area insonated was approximately twice the area of the transducer. The area insonated was marked in such a way that the point of pain threshold measurement was the centre of the area (See Figure 3.3). Ultrasound gel was applied over the area insonated.

The subject was seated on a chair with the arm supported comfortably in full pronation and 90 degrees elbow flexion (Figure 3.6). The machine was screened behind a curtain so

that the subject did not know the intensity of the ultrasound given. The ultrasound was given by a trained research assistant. The assistant applying ultrasound was not blinded to the experimental/control allocation.

A standard protocol of ultrasound (Dyson 1987, Griffin 1966, Holmes and Rudland 1991) was used:

Frequency : 1.1 MHz.

Intensity : 1 Watt/cm^2.

Time : 5 minutes.

Mode : continuous wave.

Method : direct contact with coupling medium (gel).

Coupling medium : Aquasonic 100, Parker Laboratories Inc, Orange, NJ 07050, USA.

Reid and Cummings (1977) reported that aquasonic gel was the most efficient of the agents investigated. The percentages of the ultrasound transmitted were 72.6% (aquasonic gel), 67.7% (glycerol), 59.4% (distilled water), 26.6% (ECG couplant), 19% (liquid parafin) and 0% (air).

The subjects were told that:

a. the gel used was a little bit cold for the first few seconds.
b. ultrasound should not produce any sensation. However, they may feel mild warm on the area treated.
c. the subject should report immediately if he or she felt any discomfort during treatment.

The transducer was moved around at the rate of about 3 cm per second. The sham ultrasound was given in a similar manner to the treatment protocol, except that the intensity was zero.

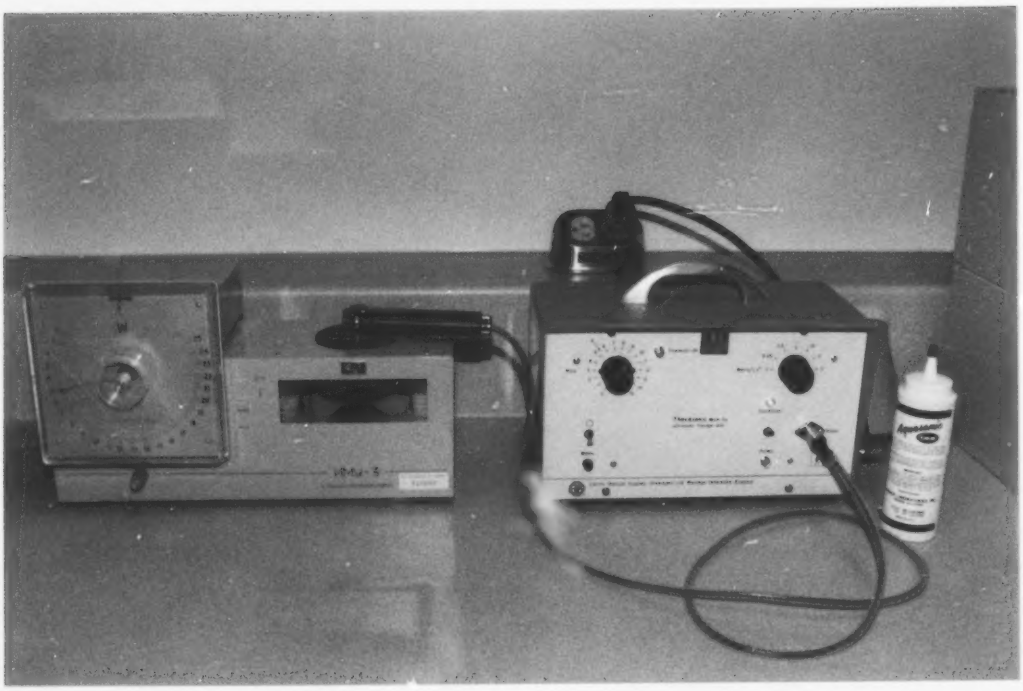

Figure 3.5. Calibration of ultrasound unit (right side) by using NMY-3 water balance (left side).

Figure 3.6. Method of application of the ultrasound treatment.

Statistical analysis.

The pain threshold measures of experimental and control arms pre and post ultrasound were presented as means and standard deviations. A three-way ANOVA with repeated measures on three factors (arm x time x site) and Newman Keul post hoc analysis were used to reveal whether ultrasound increased the pain threshold. An alpha level of 0.05 was set for the analysis.

Ethical Consideration.

The purpose and the protocol of the study were explained to the subjects. The subjects were informed that ultrasound energy was applied to the dorsal aspect of both upper forearms. The pain threshold was also measured at the same areas, before and two minutes after ultrasound.

Informed consent was obtained from all subjects. There was no obligation to participate in the study and the subject had the right to withdraw from the study at any time. Confidentiality was maintained by identifying the subjects by number only.

The pressure applied for pain threshold measurement did not cause any tissue damage because the pressure was released as soon as the subject started feeling mild dull pain. The potential risks caused by ultrasound were very low because the intensity used was well below the maximum output intensity of the ultrasound unit and within the recommended therapeutic

range of ultrasound (Williams 1983; Repacholi and Benwell 1982, Ziskin et al 1990). Ultrasound had no adverse effect, it was innocuous with perhaps only a mild sensation of warmth over the area treated. Although cavitation within tissues may occur, this side effect was unlikely to occur as long as the transducer was kept moving, the mode of the treatment was continuous wave and the intensity was within the recommended therapeutic range (Williams, 1987). The study only required one session for each subject and it took about 20 minutes.

This proposal passed the Student's Proposal Ethics and Research Review Committee prior to the implementation of the study.

Limitations and delimitations.

Limitation of the study.

The study was limited by :

a. The reliability of the pain threshold measurements with a dolorimeter. However, in a pilot study, the assessor had a test retest reliability of : 0.98.
b. The ability of the therapist to apply ultrasound in an exactly similar manner to all subjects.

Delimitations of the study.

a. The study was limited to healthy pain-free subjects.
b. The study was concerned with experimental pain evoked by a dolorimeter.

c. The ultrasound was limited to 1 Watt/cm^2 for 5 minutes using a frequency of 1.1 MHz and applied over a muscle belly in a continuous mode.

4. Results.

The raw data on pain thresholds on experimental treatment, experimental neutral, control treatment and control neutral points, pre and post ultrasound are presented in Appendix C. The means and the standard deviations of the raw data on pain thresholds are presented in Table 4.1, Figure 4.1 and Figure 4.2.

A three way Anova with repeated measures demonstrated significant interactions among arm, site and time ($p= 0.00019$). The summary of the three way Anova is presented in Table 4.2.

The results of Newman-Keuls post hoc analysis (Appendix D) support the four proposed hypotheses, ie:

a. There was a significant increase in pain threshold on the experimental treatment point following ultrasound compared with that taken prior to ultrasound.
b. There was no significant difference in pain threshold on the control treatment point between pre and post sham ultrasound.
c. The pain threshold on the experimental treatment point following ultrasound was significantly higher than that on the control treatment point following sham ultrasound.
d. There was no significant difference in pain threshold on the experimental neutral and control neutral points between pre and post ultrasound.

Table 4.1. Means and standard deviations ( )
of pain thresholds (kg/cm^2).

	Pre		Post	
	Treatment	Neutral	Treatment	Neutral
Real US	1.53 (.350)	1.95 (.541)	1.93 (.556)	1.96 (.572)
Sham US	1.49 (.317)	1.95 (.575)	1.56 (.348)	1.94 (.581)

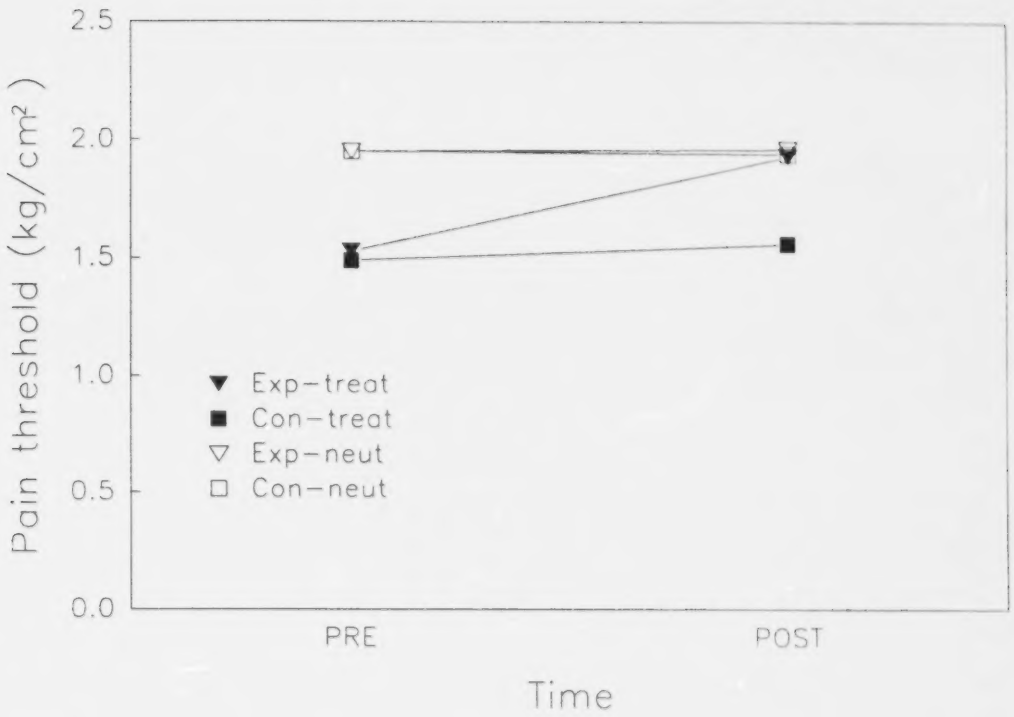

Figure 4.1. Graphic representation of means for pain threshold (Exp-treat: experimental arm - real US; Con-treat: control arm - sham US; Exp-neut: experimental arm - neutral; Con-neut: control arm - neutral).

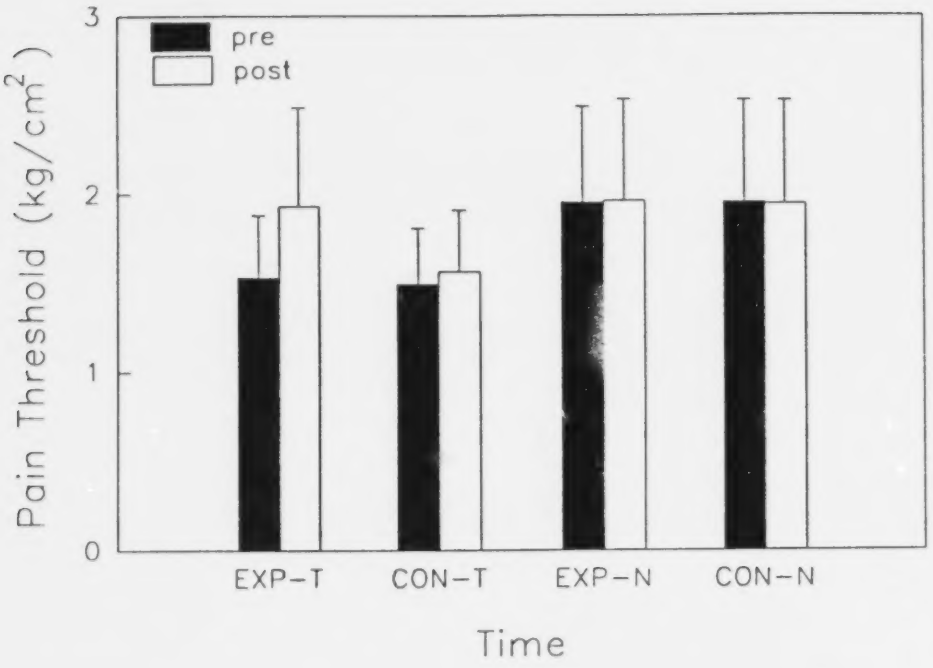

Figure 4.2. Graphic representation of means and standard deviations for pain thresholds (Exp-T: experimental - real US; Con-T: control -sham US; Exp-N: experimental - neutral; Con-N: control - neutral).

There were other findings obtained from the Newman-Keuls post hoc analysis which were not related to the proposed hypotheses, ie:

a. There was a significant difference in pain threshold between pre experimental treatment and pre experimental neutral points.
b. There was no significant difference in pain threshold between pre experimental treatment and pre control treatment points.
c. There was a significant difference in pain threshold between pre control treatment and pre control neutral points.
d. There was a significant difference in pain threshold between post control treatment and post control neutral points.
e. There was no significant difference in pain threshold between post experimental treatment and post experimental neutral points.

Eleven subjects reported that they experienced warmth on the treated area following real ultrasound.

Table 4.2. Summary table of three way ANOVA for pain thresholds.

SOURCE	SS	MS	DF	F-RATIO	PROB
Site (St)	4.19	4.19	1	18.67	.00037
Error	4.27	.22	19		
Arm (Ar)	.45	.45	1	3.00	.09959
Error	2.86	.15	19		
Time (Tm)	.54	.54	1	17.03	.00057
Error	.60	.03	19		
St*Arm	.37	.37	1	2.31	.14503
Error	3.05	.16	19		
St*Time	.54	.54	1	31.30	.00002
Error	.33	.02	19		
Arm*Tm	.30	.30	1	18.46	.00039
Error	.31	.02	19		
St*Ar*Tm	.26	.26	1	21.38	.00019
Error	.23	.01	19		

5. DISCUSSION.

The results of the study indicated that ultrasound treatment significantly increased pain threshold while sham ultrasound had no effect. In the following discussion, potential mechanisms for the pain relief from ultrasound will be considered. In addition, the results of the present study will be compared to results from the literature. Possible sources of error and clinical relevance of the results will also be discussed.

The increase in pain threshold could be due to the thermal effect of the ultrasound. Eleven subjects reported that they experienced warm sensation on the treated area indicating that the ultrasound may have produced heat in the tissues insonated. However, the tissue temperature was not measured in the present study. Lehmann et al (1958) also reported that ultrasound increased tissue temperature. They stated that heat was involved in the mechanism of the increase in pain threshold, but no data was provided to support the statement.

The thermal effect reported by a number of subjects in the present study is not in agreement with that reported by Kramer (1985). Kramer (1985) reported that ultrasound at 1.0 watt/cm^2 for 5 minutes produced a decrease in subcutaneous temperature by 0.1^{o} C. However, the area the investigator insonated was large (60 cm^2) compared with the size of the

transducer used (10 cm^2) so that the heat produced may have been low and absorbed by the ultrasound gel. If the heating effect of the ultrasound was less than the cooling effect of the gel, the result would be a decrease in tissue temperature. Summer and Patrick (1964) suggested that the area insonated should be about twice as large as the transducer. No data was provided to support the statement. Using continuous ultrasound at 1.9 watts/cm^2 for 5 minutes, Madsen and Gersten (1961) found that the temperature rise in tissues was doubled when the insonated area was decreased by one-half.

An increase in pain threshold by heat could be due to a neurogenic response occurring at the pain receptors. Bishop (1980) hypothesized that a pain stimulus was received by receptor substances such as substance P (an 11-amino acid peptide) at the sensory nerve ending. The action of the receptor substance was terminated by a degrading enzyme surrounding the nerve terminals. Fischer and Solomon (1965) reported that a temperature rise enhanced the activity of an enzyme in vitro. Thus, if Bishop's hypothesis is true, the activity of the degrading enzyme surrounding the nerve terminals may have been enhanced by the thermal effect of the ultrasound resulting in a decrease in the receptor activity. This process would lead to an increase in pain threshold.

The gate control mechanism (Melzack and Wall 1965) may be another possible explanation for the increase in pain threshold with heat. Using rats for experiments in vivo,

Matzner and Devor (1987) reported that warming the afferent A-fibers from 33° C to 42° C resulted in a gradual increase in the firing rate from 20 to 29 impulses per second. The A-fibers were unlikely to be the A-delta type (pain fibers) because the A-delta fibers were excited only at temperatures above 43° C - A delta type II - and above 49° C - A delta type I (Campbell et al 1989). In contrast to the A-fibers, the C-fibers had a decrease in firing rate with heating (Matzner and Devor 1987). The investigators stated that these findings may explain the mechanism by which heat relieves pain. Excitation of the A-fibers would block transmission of the pain fibers resulting in closing the gate. A suppression of the C-fibers carrying pain stimuli would also result in a higher pain threshold.

Although the tissue temperature was not measured in the present study, this should be between 33° and 42° C following ultrasound. Abramson et al (1960) reported that the average temperature of subcutaneous tissues in the forearm at room temperature was 35.1° C. Without providing the data, Williams (1987) reported that the temperature rise in most soft tissues by ultrasound of 1 MHz at 1.0 watt/cm^2 was about 0.86° C per minute in the absence of heat removal by blood flow and conduction. Thus, the maximum temperature rise by five minutes insonation should be 4.3° C (5 x 0.86°) and the tissue temperature following ultrasound should not exceed 39.4° C (35.1° + 4.3°). This was within the range of temperatures used

by Matzner and Devor (1987).

Non-thermal effects such as histamine release and vibration were unlikely to be responsible for the increase in pain threshold. Using rats for experiments in vivo, Fife and Chahl (1984) reported that ultrasound released histamine from mast cell degranulation. The histamine increased local blood circulation resulting in the removal of pain mediators (Michlovitz 1986, Newton 1986). However, this mechanism was unlikely to occur, because the subjects had neither pain nor pathology.

As discussed in the literature review, vibration produced by ultrasound was unlikely to be responsible for the increase in the pain threshold because the frequency of 1.1 MHz was too high to excite nerve fibers (Lundeberg et al 1984, Ribot-Ciscar et al 1989). Ribot-Ciscar et al (1989) indicated that mechanoreceptors can only respond to vibrations up to 280 Hz.

To determine whether heat is the main mechanism for the increase in pain threshold, it would be necessary to conduct a study using different protocols, eg: pulsed ultrasound, continuous ultrasound and sham ultrasound. If heat is responsible for the increase in pain threshold, the increase in pain threshold will only occur with continuous ultrasound. If there is a non-thermal mechanism, the increase in pain threshold will occur with both pulsed and continuous ultrasound.

There was no significant increase in pain threshold

following sham ultrasound. This finding indicated that there was no placebo effect produced by sham ultrasound. As stated by Fields and Levine (1984) in their review, experimental pain might not be of sufficient duration or intensity to trigger the endorphin mediated analgesia system without some other manipulations. The endorphin mediated analgesia system is thought to be involved in the relief of pain from placebo.

The placebo effect produced by sham ultrasound has been studied by some investigators (Binder et al 1985, Haker and Lunderberg 1991). Binder et al (1985) reported that there was no placebo effect produced by sham ultrasound in their study of 76 patients with lateral epicondylalgia. But, Haker and Lundeberg (1991) found that both treatment and placebo groups of patients with lateral epicondylitis showed significant decreases in pain and there was no significant difference in pain relief between the two groups. The different results may be due to the chronicity of the conditions. Binder et al (1985) treated patients with a mean duration of pain of 4.3 months (placebo group) and 4.8 months (treatment group) while Haker and Lundeberg (1991) treated patients with a median duration of pain of 8 months (treatment group) and 9 months (placebo group). Patients with chronic pain frequently become depressed (Clark Mims 1989). Placebo treatment was reported to have an impact on unpleasantness - one of the emotional aspects of pain - rather than sensory qualities of painful events (Craig 1989). Thus, a placebo effect may be more likely

to occur in more chronic pain.

There was no significant change in pain threshold of the neutral area, either on the experimental or control arm following ultrasound. This is further evidence that ultrasound does not produce a systemic effect on pain. Lehmann et al (1958), Stewart et al (1982) and Anderson et al (1951) reported that the effect of ultrasound was limited to the area supplied by the insonated nerve, including innervated areas distal to the site of application. However, in the present study, a distal point was not tested.

Pain threshold was found to be similar on the same part of the body bilaterally. This finding is in agreement with those reported by Fischer (1987), Gerecz-Simon et al (1989) and Hogeweg et al (1992).

Pain threshold on the dorsal aspect of the forearm was significantly lower than that on the ventral aspect of the forearm. Other investigators (Fischer 1987, Ohrbach and Gale 1989 and Brennum et al 1989) have reported that pain threshold is significantly different on different parts of the body. The subcutaneous fat on the ventral aspect of the upper forearm has been found to be thicker than that on the dorsal aspect (Edwards 1950, personal experience on a cadaver dissection 1993) and may be responsible for the higher pain threshold.

There may be some sources of error affecting the result of the study such as subjects' bias, tester's bias and instrument error. However, those errors were unlikely to occur

in the present study.

The subjects may unintentionally increase the pain threshold following treatment ultrasound to please the investigator. However, this was unlikely to occur because they did not know which arm was experimental. In addition, they were not allowed to see the pain threshold values. Warm sensation experienced by a number of subjects may have suggested to them that the treatment was more effective. However, they were naive to ultrasound and did not know which treatment was supposed to increase the pain threshold. The subjects were told that the treatment on each side of the forearm was at different intensities. They were not told that one of the treatments was at zero intensity.

The tester's bias was also unlikely to affect the results. The tester did not know which arm was experimental until the data collection was finished.

Another potential source of bias was the research assistant administering the ultrasound because he was not blinded to the treatment allocation. However, he was given a strict procedure to follow. He did not tell subjects the allocation of the experimental/control arm or which treatment was supposed to increase pain threshold. Thus, this bias was unlikely to occur.

It was unlikely that there was an instrument error. The intensity output of the ultrasound unit was tested prior to the commencement of the study, at the middle and at the end of

the study. It was found that there was no change in the intensity output throughout the study. The dolorimeter has been found to be reliable (McCarty et al 1965, Reeves et al 1986, Ohrbrach and Gale 1989, Brennum et al 1989, Dahl et al 1990).

Clinical relevance.

The results of the study indicated that ultrasound at 1.0 watt/cm^2, continuous wave, applied for five minutes significantly increased the threshold of dull pain. There is support for generalizing the result to at least the sensory aspect of clinical dull pain. Both experimental and clinical dull pain are served by the same fibres, ie C-fibres (Dwarakanath 1991). However, the generalisability of the results of an experimental pain study may not be perfect (Wolff 1983) because:

a. The experimental dull pain is acute in nature while the clinical pain can be acute or chronic.
b. The experimental pain is primarily concerned with the sensory aspect of pain while clinical pain also has another two components of pain, ie affective (psychological) and cognitive components.

There are some other problems in generalizing the results of the experimental pain study to a clinical population. Luckhurst et al (1992) found that the intensity of clinical pain was not well correlated to pain thresholds (r= 0.111 to -

0.071). Even though there is a poor correlation between pain threshold and pain intensity, studies (Keele and Lond 1954, Harris and Rollman 1983) have shown that pain threshold is a valid measure of pain sensitivity. As discussed in the literature review, the results of these studies indicated that pain threshold evoked by a dolorimeter had a good correlation with other pain measures using cold and electrical stressors. Pain threshold in the experimental study is a measure of pain sensitivity of normal tissues to an external stimulus (Brennum et al 1989) while pain intensity is a perceived pain in pathological tissues and is influenced by affective and cognitive, as well as sensory factors (Wolff 1983, Paris et al 1988). Thus, pain threshold may not be a perfect reflection of pain intensity.

Jaeger and Reeves (1986) reported that the substantial reduction in algometer readings of trigger point sensitivity in their patients with myofascial pain following cooling and stretching were consistently accompanied by large decreases in VAS pain intensity ratings, even though the correlation was not significant. The non-significance of the correlation was said to be due to the fact that there were many trigger points in each patient while the algometer measurement was only taken on one point.

The measurement of pain threshold appears to have validity from a physiological point of view. Zimmermann (1984) reported that the nociceptor threshold was lower than the

threshold of pain perception. This was said to be due to the pain perception modulation within the central nervous system. However, Gybels et al (1979) reported that the firing rate of C-nociceptors and the subjective intensity of pain both increased with strength of the stimulus. The nociceptor discharge and the subjective ratings were graphically reported to be in a close correlation. Thus, pain threshold is related to physiological response of the pain receptors.

Another factor to consider is the duration of pain relief. In this study, the pain threshold was measured 2 minutes following ultrasound. It is not known how long the pain relief lasted. Therefore, there can be no generalisation of the result to long term relief of clinical pain.

To clarify the generalisability of this result to clinical pain, it would be beneficial to examine the effect of ultrasound on pain threshold in persons with clinical pain. It would also be useful to compare the efficacy of different regimes of ultrasound (eg: different intensities and times).

6. SUMMARY AND CONCLUSION.

The main purpose of the study was to examine the effect of ultrasound on pain threshold. Twenty subjects (12 male, 8 female) ranging in age from 22 to 51 years participated in the study.

Pain threshold was taken on the dorsal and ventral aspects of both upper forearms with a dolorimeter before and after ultrasound or sham ultrasound treatment. The dorsal aspects were randomly allocated into experimental and control areas while the ventral aspects were assigned as neutral areas. Ultrasound of 1.1 MHz was applied at 1.0 watt/cm^2, continuous wave for five minutes to the experimental area. The control area was given sham ultrasound (0.0 watt/cm^2 for five minutes).

A three way ANOVA (Arm*Site*Time) and Newman-Keuls post hoc analysis revealed the following:

a. There was a significant increase in pain threshold following treatment ultrasound.
b. There was no significant increase in pain threshold following sham ultrasound.
c. Pain threshold following treatment ultrasound was significantly higher compared with that following sham ultrasound.
d. There was no significant change in pain threshold on neutral areas following treatment or sham ultrasound.

It is concluded that continuous 1.1 MHz ultrasound

applied at 1.0 watt/cm^2 for five minutes can increase threshold of dull pain in healthy subjects.

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APPENDIX A

INTRODUCTORY INFORMATION.

INTRODUCTORY INFORMATION

A STUDY ON THE EFFECT OF ULTRASOUND ON PAIN THRESHOLD.

Dear _____

Pain is the most frequent complaint that motivates patients to seek treatment, and is one of the symptoms for which ultrasound is recommended.

The purpose of this study is to examine the effect of ultrasound on pain threshold. The subjects will be healthy pain-free volunteers, have no known or suspected upper extremity or cervical pathology, no previous surgery of upper extremity, no previous experience with ultrasound, not taking any medication, or not pregnant.

The pain threshold will be measured before and immediately after ultrasound on the dorsal and ventral aspects of the upper forearms with an increasing pressure through a 1.0 cm^2 surface area. The pressure will be increased gradually up to the point at which the subject starts feeling uncomfortable (not painful) and then released immediately.

Ultrasound is used regularly and safely in physiotherapy clinics. In this study, both upper forearms will be given ultrasound for five minutes each with different intensities. The highest intensity given will be 1.0 watt/cm^2, well below the maximum output intensity of the ultrasound unit (3.0 watts/cm^2).

The study will be conducted in Room 179 Corbett Hall, University of Alberta. The total time for each subject should be about 20 minutes.

The result of the study will be useful for physiotherapists in the management of pain. Voluntary participation will be needed. Each subject will have the right to withdraw from the study any time. Any information obtained in the study will be kept confidential.

If you are interested in participating in this study, please contact one of the following people:

N a m e : Sri Mardiman.	Name : Dr. J.Wessel.
Room : 171 Corbett Hall.	Room : 250 Corbett Hall.
Phone : 439 1328 (Home).	Phone : 492 2988.

Thank you very much for considering my request.

Yours truly,

Dr. J. Wessel.
Supervisor.

Sri Mardiman.
Investigator.

APPENDIX B

CONSENT FORM.

CONSENT FORM.

Title : **The Effect of Ultrasound on Pain Threshold.**
Investigator: Sri Mardiman, physiotherapy graduate student, University of Alberta, phone 439 1328 (home).
Supervisor : Dr. J. Wessel, 250 Corbett Hall, phone 492 2988.

I,_____, voluntarily consent to participate in a research project conducted by Sri Mardiman, physiotherapy graduate student, and supervised by Dr J Wessel. The study is to examine the effect of ultrasound on pain threshold. It is conducted in Room 179 Corbett Hall, University of Alberta.

I have been informed that pain threshold will be measured on the dorsal and ventral aspects of both upper forearms with an increasing pressure using a dolorimeter. I will be asked by the investigator to state at what point I start feeling mild discomfort. At this point the pressure will be released immediately. I understand that the measurement of pain threshold will be taken before and immediately after ultrasound.

I have also been informed that ultrasound will be applied to the same areas where pain threshold measurement are taken. Ultrasound will be given for five minutes to each arm with different intensities. The study is done in one session for about 20 minutes.

I understand that ultrasound is used regularly and safely in physiotherapy clinics. During treatment the ultrasound head will be continuously moved around and the intensity will be kept low so that there will be no risk of tissue damage.

I understand that the investigator will be pleased to answer any question that I might ask concerning the study. I may withdraw from the study at any time without prejudice.

Any information obtained in this study will be seen only by the investigator and those individuals associated with the research. The information that will be published or presented will not refer to me by name, but by code number.

With my signature below, I indicate that I understand all requirements in this study.

Subject : _____ Date : _____

Investigator : _____ Date : _____

Witness : _____ Date : _____

APPENDIX C

RAW DATA ON PAIN THRESHOLD.

Appendix C

Raw data (kg/cm^2) on pain threshold.

No.	Gender	E1	E2	C1	C2	NE1	NE2	NC1	NC2
01	M	1.3	1.8	1.5	1.8	1.6	1.7	1.8	1.9
02	M	1.2	1.3	1.5	1.4	1.6	1.6	1.8	1.7
03	F	1.0	1.3	1.3	1.6	1.2	1.0	1.0	1.0
04	F	1.4	1.8	1.3	1.1	1.7	1.6	1.6	1.5
05	M	1.6	2.6	1.6	2.1	2.3	2.5	2.3	2.4
06	M	1.9	2.4	1.4	1.4	1.8	1.9	1.8	1.8
07	M	1.4	1.6	1.4	1.5	1.6	1.6	1.5	1.4
08	M	1.6	1.9	1.4	1.5	1.6	1.6	3.0	2.8
09	F	1.1	1.1	1.1	1.3	1.2	1.1	1.3	1.2
10	M	2.5	3.4	2.1	2.1	2.6	2.8	2.6	2.8
11	F	1.5	2.5	2.1	2.0	2.6	2.6	3.0	3.0
12	F	1.5	1.8	1.7	1.7	2.3	2.2	2.2	2.2
13	F	1.7	1.8	1.6	1.4	1.6	1.7	1.6	1.7
14	F	1.4	2.0	1.2	1.5	2.5	2.4	2.5	2.5
15	F	1.4	2.0	1.3	1.2	2.0	2.1	1.6	1.5
16	M	2.1	2.6	2.1	2.3	2.5	2.5	2.1	2.1
17	M	1.8	2.0	1.3	1.4	2.6	2.5	2.6	2.5
18	M	1.6	1.7	1.7	1.6	2.8	2.8	1.5	1.5
19	M	1.3	1.8	1.3	1.3	2.0	2.0	2.0	2.1
20	M	1.3	1.2	1.0	1.0	1.0	1.0	1.2	1.3

Legend: E = experiment
1 = before ultrasound
C = control
2 = after ultrasound
N = neutral area.

APPENDIX D

Summary of the result of Newman-Keuls post hoc analysis for pain thresholds.

Summary of the result of Newman-Keuls post hoc analysis for pain thresholds.

Arm	ST	TM		1	2	3	4	5	6	7
1. Ct	Rx	Pre								
2. Ex	Rx	Pre	Req df	.19						
			Obs df	.03						
3. Ct	Rx	Post	Req df	.11	.19					
			Obs df	.06	.03					
4. Ex	Rx	Post	Req df	.25	.11	.19				
			Obs df	.43*	.40*	.37*				
5. Ct	Nt	Post	Req df	.30	.27	.25	.20			
			Obs df	.45*	.41*	.38*	.01			
6. Ct	Nt	Pre	Req df	.30	.29	.28	.25	.09		
			Obs df	.45*	.42*	.39*	.02	.005		
7. Ex	Nt	Pre	Req df	.31	.30	.29	.28	.23	.19	
			Obs df	.46*	.42*	.39*	.02	.00	.005	
8. Ex	Nt	Post	Req df	.33	.32	.30	.29	.25	.23	.09
			Obs df	.46*	.43*	.40*	.03	.01	.00	.005

Legend: Ex= experimental. Ct= control. ST= Site.
Nt= neutral. Req= required. TM= Time.
df= difference. Obs= observed.
* = significant ($p \leq .05$).